UNIT 10 ENERGY RESOURCES

Structure

10.1 INTRODUCTION

Growing population and associated developments increase the energy demand. We constantly transform energy into heat, light and motion. Access to energy is essential for human development and for poverty eradication. However, evolution and trend in energy use and energy mix determines the energy security of nations, toxic emissions in cities and the extent of greenhouse gas emissions that cause global warming and destabilize climate.

Energy demand is expected to grow more rapidly in the future due to population growth and lifestyle changes, increase in the level of economic activities such as mobility, information processing, manufacturing and growth of cities. Two-third of world's energy is consumed in cities – by half of world's population. By 2030, cities will be consuming 73 per cent of world's energy.

At the same time, developing countries like India have an added challenge of meeting human development goals that will further increase demand for primary energy. India's current consumption of energy is quite low and so is the energy related greenhouse gas emissions compared to the industrialized countries. This is mainly because millions of poor households do not have access to modern

energy. But this is expected to grow with growing affluence and increased access to electricity and other energy sources.

Therefore, the challenge before India and other developing countries is to plan its energy transition well. They can avoid energy intensive growth with energy efficiency and conservation measures and low carbon strategy during the early stages of growth. They need to ensure equitable access to energy. This can curb energy demand without compromising human development and poverty eradication goals. This can avoid substantial increase in future emissions, and, strengthen energy security. You will learn about these issues in this unit.

10.2 OBJECTIVES

After studying this unit, you should be able to:

- explain different types of energy sources, their potential and constraints; and
- discuss energy security from the perspective of climate change, energy consumption, energy efficiency, and renewable energy.

10.3 OVERVIEW OF ENERGY SOURCES

Let us first understand the primary energy sources that drive our economy and lifestyle. We can harness an amazing range of conventional and non-conventional or renewable energy sources.

- **Fossil Energy:** Petroleum, natural gas, and coal are examples of stored chemical energy in fossil fuels.
- **Nuclear Energy:** It is stored in the nucleus of an atom and very large amounts of energy can be released when the nuclei are combined or split apart.
- **Renewable Energy:** These include geothermal heat; gravitational force of tides and hydropower, rotational forces of ocean currents, the solar flux including wind, waves and sunlight, etc. These can be extracted, collected, concentrated, transformed, transported, and distributed as needed.

The mix and extent of the use of these energy sources vary quite widely across sectors and countries.

10.3.1 Non-renewable Energy Sources

The conventional energy sources, mainly the fossil fuels that dominate our energy system today are exhaustible. Fossil fuels such as petroleum, natural gas, and coal take millions of years to form and are practically considered 'non-renewable'. Fossil fuels dominate the global energy markets to meet the ever-increasing demand for heat, electricity and transport fuels. These fuels are responsible for both toxic pollution and heat trapping gases like carbon dioxide. Combusting fuels at increasing rates will release more carbon and add to the existing carbon stock. At a global scale, fossil fuel account for around 70-80 percent of total energy related warming emissions including carbon dioxide, methane and some traces of nitrous oxide. In most of our cities combustion

of these fuels spew sulphur dioxide, carbon monoxide, particulate matter, nitrogen oxides and a range of toxic gases that have serious health effects.

In India, fossil fuels dominate the fuel basket just as in other parts of the world. The share of coal in India's primary energy is more than 40 percent, nearly same for oil and gas. In the specific sector of electricity generation, coal continues to dominate at 72 percent. Coal will remain important energy source until 2030. World and India will require massive transformation in energy system to reduce dependence on fossil fuels to combat global warming.

10.3.2 Renewable Energy Sources

Energy that can be naturally replenished is renewable energy. This includes traditional biomass like firewood, agro-waste, dungs and also new renewables like small hydro, biofuels wind, solar, geothermal, tides, and geothermal heat. These are considered environmentally sustainable as they are low to zero carbon fuels.

The actual share of modern renewables of solar and wind energy, etc. in India is significantly low (about 2 percent of the total). But the renewable energy's share of total electric capacity is more than twice that of the US, and India is among the top five countries in renewable capacity. Future strategies will have to enable more rapid expansion of the renewable energy programme.

Why traditional biomass is low carbon fuel? Biomass has carbon. But this carbon is part of the current carbon cycle. The carbon that already exists in the atmosphere is absorbed during the growth of the plants. During photosynthesis, the trees store carbon in their woody tissue and oxygen is released back to the atmosphere. As the wood is burned, the carbon stored in the woody tissue combines with oxygen to produce carbon dioxide, this is emitted back and returned to the atmosphere. As a result, a sustainable balance is maintained between carbon emitted and absorbed. There is no net addition of carbon. The challenge is therefore to innovate to burn this fuel clean to minimise health impacts while benefiting from its low carbon potential.

Check Your Progress 1

Note: 1) Use the space given below for your answers.
2) Check your answers with those given at the end of this unit.

1. Elaborate the different types of energy sources.

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2. Why traditional biomass is carbon neutral?

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10.3.3 Trends in Energy Consumption

Global primary energy demand has grown phenomenally. International Energy Agency projects that this will continue to grow by more than half between 2005 and 2030. Fossil fuels will form 84 per cent of overall increase in global demand between 2005 and 2030. In the global fossil fuel basket, oil is the single largest fuel though coal has witnessed the biggest increase in consumption. Currently, the industrialized countries have the maximum share of energy consumption. The developing countries are also expected to see significant increase as their economies begin to grow.

India's Integrated Energy Policy of 2006 says that if India needs to sustain 8-10 per cent increase in economic growth rate over next 25 years to eradicate poverty and meet human development goals, India will have to increase primary energy supply by 3-4 times and electricity capacity generation by 5-6 times from 2003-04 levels. As a result, India will have to expand its energy resource base, seek new energy sources, and make energy use more efficient.

However, despite the growth in energy demand by 3.5 per cent per annum, energy demand per capita has remained extremely low in India – one of the lowest in the world. It is one tenth of the average of the OECD countries. This is largely because of India's large rural population. Also the gains from recent growth have not flowed proportionately to the poor. In 2005 the bottom 40 percent still consumed only 13 percent of electricity demand. The World Bank estimates that despite declining poverty rates, the absolute number of poor in Indian villages has hardly reduced. Therefore, leapfrogging to modern renewable and sustainable use of traditional biomass will play a role in Indian villages. However, economic growth, urbanization and changing lifestyle will be the main drivers of energy demand.

10.3.4 Trends in Energy Intensity

It is also possible that while absolute energy consumption increases, efficiency of energy use can improve. There is a difference between the absolute increase in energy consumption and trend in the energy intensity. If we can use our energy more efficiently to produce a unit of output the energy intensity will decline and make our energy use more efficient. The energy intensity is the measure of total energy per unit of gross development product.

The projected global primary energy intensity is actually falling on an average by about 1.8 per cent per annum globally over 2005-2030 period. Why? Rapid changes in the economy that is moving away from heavy manufacturing towards lighter industries; increase in share of less energy intensive service activities; and overall efficiency gains due to improved technologies.

According to the India's Integrated Energy Policy energy intensity of India's growth is falling and is about half of what it used to be in early seventies. The Integrated Energy Policy estimates that India's energy intensity can be cut by up to 25% from current levels through efficiency measures. Currently, India consumes 0.16 kg of oil equivalent (kgoe) per dollar of GDP expressed in purchasing power parity terms. India's energy intensity is lower than the 0.23

kgoe of China, 0.22 kgoe of the US and a World average of 0.21 kgoe. Lowering the energy intensity of GDP growth through higher energy efficiency is important for meeting energy challenge and ensuring energy security.

India's advantage is the rapid growth of the service sector at a rate well above industry growth. Services are less energy consuming than manufacturing. Services contribution to the economy has grown from 44 percent in 1990 to 54 percent in 2018. If this continues, energy intensity will decline further. Another reason is relatively high prices of industrial energy and electricity. This has restrained energy demand and reduced energy intensity of industries. Steel and cement industries are important examples. All new industrial plants can adopt technologies that can improve energy efficiency from the current 36 percent to at least 38-40 percent.

10.4 ENERGY SECURITY

To meet the basic needs of economic and human development, countries have to ensure adequate, affordable, reliable supplies of energy, diversity of primary energy mix and fuel substitution. This reduces risks in an energy constrained world and in nutshell called energy security.

India cannot satisfy its full energy needs from the energy produced domestically. India's import dependence is steadily increasing. India's Integrated Energy Policy states that India would need to import some 40-45 percent of its total commercial energy requirement by 2030 compared to the current level of under 30 percent today. Even to ensure that import dependence does not exceed 40 per cent, domestic commercial energy supplies will have to rise four times in aggregate over the next 25 years.

India is already importing nearly 75 per cent of its petroleum crude requirements. It is also importing liquefied natural gas and coal. This makes India vulnerable to vagaries in international fuel supplies and prices. Therefore, the energy transition will have to be well managed to maximize energy efficiency and savings and substitution with low carbon energy.

10.4.1 Energy and Climate Change

Increasing energy consumption results in diverse environmental problems. Greenhouse gases emissions too increase due to increased energy consumption particularly the burning of fossil fuels. As per the Paris Agreement, we must take measures to limit GHG so that global mean surface temperature is well below 2°C from the pre-industrial levels. To achieve the WB2C (well below 2°C) goal, we must take measures to "reduce the GHG emissions by 50-85% on 2000 levels by 2050". The IPCC also has stated that in order to stabilize the GHG emissions, the global emissions must plateau and thereafter reduce. In order to achieve the goals of Paris Agreement, we need to be innovative and also transform the energy use strategies.

Reducing fossil fuel energy consumption is a difficult challenge. For instance, despite the commitment of the industrialized countries under the Kyoto protocol of the international climate convention to reduce their CO_2 emissions from the 1990 levels, emissions have actually increased. Their emissions from energy

producing facilities have jumped by 24 per cent and transport emissions by 28 per cent between 1990 and 2005. Emissions are still increasing when emissions will have to be cut by 50-85 per cent.

Since the fossil fuel energy is comparatively cheap and abundant, their use is difficult to contain. Indeed, fossil fuel meet 80% of world primary energy demand and also it is reported that its use is likely to increase in the coming 30 years, provided if the policies pertaining to "low carbon emissions" are promoted on war footing. As regards GHG emissions by India, the energy sector contributes about 60% and hence there is a dire need to promote low carbon emission technologies and low carbon pathways.

10.4.2 Energy Consumption and Equity

Even as the world takes step to drastically cut energy use and emissions, it must not compromise human development goals. We need to use commercial energy more equitably to protect every human's development rights and use new technologies and save fuels to deliver a threshold level of development.

Do you know, there is enormous difference in the carbon emissions of nations? The more prosperous a country's economy is, and the higher its per capita income and fossil fuel use, higher is the per capita emissions. Although every human being contributes to carbon dioxide concentrations in the atmosphere, the person's life-style decides the amount that is emitted.

The prosperity of the industrialized nations have caused years of 'historical' emissions that have been accumulating in the atmosphere since the start of the Industrial Revolution. The CO_2 emissions stay in the atmosphere for more than 100 years. The emissions since the 1800, when the western world was industrializing, is still in the air and has caused most of the warming already.

Now, what will developing countries do? Their per capita emissions are still comparatively low. But their emissions will increase as they industrialize rapidly and build their infrastructure. They therefore need the atmospheric space to emit and grow but sustainably. India with over 17 per cent of the world's population has access to only about 3.8 per cent of world's commercial energy. Even though India is the fourth largest emitter of carbon dioxide in the world, its per capita carbon footprint is less than one-tenth of that in high-income countries. The per capita emission of CO_2 from fuel combustion in the US is still roughly 20 tonnes per year; between 6 tonnes and 12 tonnes for most European countries; and in case of India, it is only 1.1 tonnes.

To meet its human development and poverty eradication goals, India would need to increase its energy use by 2031-32. But even then India's per capita energy consumption will remain just about 74 percent of the current global average. On considerations of equity alone, therefore, India will need a certain level of energy consumption by 2031-32. India and other developing countries can grow only if there is an international agreement by which the industrialized countries reduce their fossil energy consumption and emissions drastically to create atmospheric space for the developing and poor countries to grow. Through the United Nations Framework for Climate Change, the global emissions budget will have to be distributed among nations equitably recognizing that each individual

has equal entitlement to global atmospheric commons. This requires sharing of the growth between nations and between people while future growth happens on the basis of low carbon energy pathways.

10.4.3 Managing Energy Transition

The energy impact of the economic growth can be minimized in a variety of ways. Countries can use technologies that are more energy efficient, adopt energy conservation measures in all sectors so that absolute fuel savings is possible, expand use of low carbon and carbon neutral energy sources, achieve zero emissions and curb demand for energy. But each of the energy systems and approaches has their unique potential and constraints that need to be understood for effective planning and implementation.

10.4.4 Energy Efficiency

Lesser the energy input per output more efficient is the process and less fuel we use. Energy efficiency is the ratio between output of an energy service like light, heat, mobility – and the input of energy. There is considerable scope for further improvement in energy savings in sectors that are still inefficient.

Various strategies have been identified in the Enhanced Energy Efficiency Mission under National Action Plan on Climate Change in India. This has proposed market based mechanism to promote energy efficiency in large industry and facilities; rapid shift towards energy efficient appliances and use of demand management programmes for reducing demand for energy. This also includes energy efficiency regulations for vehicles that guzzle enormous amount of fuel. As coal is a dominant fossil fuel in our energy basket, efficiency measures are very important. Synthesis of five climate studies in India under the aegis of Ministry of Environment and Forests shows that India will massively expand energy infrastructure between now and 2030. This needs technologies viz. clean coal and otherwise to 'avoid' substantial increase in emissions. The average gross efficiency of coal power plants can be improved substantially from 30.5 percent to 38-40 percent. Thus, a very high priority should be given to increasing the thermal efficiency of current technology. For example, Integrated Gasification Combined Cycle (IGCC) can give 50 per cent efficiency. The challenge is to lower costs and make it work with different kinds of coal. The other emerging option is the CO_2 from the power plant is captured, compressed and transported for underground storage. But this technology of carbon capture and storage are uncertain. This is currently being done in Norway, North Dakota and Algeria. But there are concerns over costs and safety.

10.4.5 Potential and Constraints of Less Carbon Intensive Fuels

Shift to fuels with lower carbon content and carbon intensity is the need of the hour. For instance, coal emits almost 75 percent more carbon per unit of energy contained in the fuel than natural gas and one third more than oil. So switching from coal to oil and from oil to gas reduces emissions per unit of energy consumed. However, each energy system will have its unique potential and constraints.

Hydro Power

There is large unexploited hydro power potential in India. But this will have to be planned to overcome constraints. For instance, storage of water for hydel projects often involves displacement of people and submergence of land as in the case of Narmada dam and Tehri dam. Also, storage schemes may have other environmental consequences. These problems are not unsurmountable. But they have not been adequately attended to in the past.

Natural Gas

Natural gas is less carbon intensive than conventional liquid fuels. It is estimated that global demand for gas will expand by over half between 2006 and 2030. Most of this will be used in the power sector. Its use in the power sector accounts for 57 per cent of the projected increase in world gas demand to 2030. In India, Gas Authority of India Ltd (GAIL) is expanding the national gas grid. Nearly 200 cities can come within its ambit. However, domestic availability of natural gas cannot meet the full demand in different sectors. India is already importing natural gas.

Nuclear Energy

Nuclear power supplies about 6 percent of the world's primary energy and 15 per cent of electricity (less than renewables and hydro supply). The bulk of this, about 85 percent is in industrialized countries. Future addition of at least 1,000 megawatts of electricity by 2050 can help 'avoid' 1,800 million tonnes of carbon equivalent emissions from coal-fired plants globally. But this is possible only if costs reduce substantially. The capital costs of nuclear plants are more than double the cost of pulverized coal plants.

India is also planning to expand this power source to ensure long-term energy security. Integrated Energy Policy estimates that even if a 20-fold increase takes place in India's nuclear power capacity by 2031-32, the contribution of nuclear energy to India's energy mix is, at best, expected to be 4.0-6.4 percent. The major barriers are: long-term fuel resource constraints without recycling; economics; safety; waste management; security; proliferation, and adverse public opinion. India is also constrained by limited availability of Uranium.

Biofuels

Biofuels are processed from vegetative sources. The biofuels widely used today are largely ethanol from corn and sugarcane and are blended with petrol. Biodiesel produced from variety of crops including soyabean, jatropha, pongamia, etc. is blended with diesel. But these traditional biofuels have marginal climate benefits as their production and processing are energy intensive on a lifecycle basis. But the new generation biofuels that include cellulosic feedstocks derived from waste, agricultural residue, energy crops grown on degraded lands can give GHG benefits of 50-80 percent. Therefore, biofuels should be assessed on the basis of lifecycle emission. India is also expanding biofuel programme based on non-edible tree crops—jatropha for example—grown on wasteland. This will need proper policy safeguards to protect food and ecological security.

On the flip side, energy plantation can lead to extensive land-use changes. Cropped areas and forests can be diverted to produce biofuels. This can adversely affect food security. The Food and Agriculture Organization (FAO)

says food prices will increase between 20 and 40 percent in the next 10 years or so because of this switchover. Also if forests are cut to expand biofuel crop cultivation; this will accelerate climate change. Biofuels can be a part of the climate solution, if they are used to help the world's poor to leapfrog to a non-fossil fuel-based energy future. Most of the Indian or African villages are not connected to the electricity grid. Instead of bringing fossil fuel long distances to feed these villages, biofuels can power their future.

10.4.6 Potential and Constraints of New Renewable Energy

The transition from "fossil fuel based economy" to "low or zero-carbon energy economy" would create "environmental space" which provide enabling condition for economic growth. Nevertheless, the new renewables such as solar, wind, geothermal energy, etc. contribute about 0.5% of world's primary energy usage. The renewable energy contribute about 18% of global electricity production. Globally, the renewable energy market is steadily growing. The "National Solar Plan" of India states that about 5000 trillion Kwh of energy is estimated as the solar energy potential of India. In fact, most parts of India receive about 4-7 Kwh per square meters per day. Solar energy can be used to cater the needs of "rural electrification" and also to meet the "peak power demand". Presently, the solar technologies are said to be expensive. However, the technology development and economics of scale would reduce the cost involved in solar technology. As regards the wind energy, about 70% of renewable energy in India is contributed by wind energy. It is reported that the contribution of wind energy to India's energy mix would be less than 10 Mtoe.

10.4.7 Enabling Renewable Energy

Renewable energy will need policy support to achieve scale and cost reduction. Large scale generation will encourage innovation, improve efficiency and reduce marginal costs. Its cost can even become competitive with coal. India's Solar Mission has proposed various measures. These include solar rooftop or onsite solar photovoltaic application. Solar generation capacity to be at least 5 percent of total installed capacity of all thermal power stations. State governments will have an obligation to buy solar power. Feed in tariff, tax holiday and duty reduction will enable rapid expansion. There can be stand-alone village power plant with micro-grid for rural electrification. All fiscal incentives are to be linked with actual generation of renewable energy instead of capital subsidy for only installation of capacity.

10.4.8 Traditional Biomass

In developing countries like India, traditional biomass is the bulk of the renewable energy use. This poor persons' fuel has so far saved the world from the tipping point of climate change. In India, the share of renewable energy is estimated to be 39 per cent, because bulk of this is biomass used by the poor to cook food and lighting. Though falling in its share of the total energy mix, biomass dependence will continue to rise till 2031-32 and beyond. This energy is managed by women who face backbreaking drudgery and health problems. This also leads to environmental damage. Therefore, there is a need to make this energy resource more sustainable, more efficient and more convenient to use. For example, wood gasification or biogas plants. Also wood plantations offer the best option for biomass based supply sources along with possessing a huge

employment generation potential. Wood plantations with a potential of yielding up to 20 tonnes of wood per hectare per year in a sustainable way can significantly expand the domestic energy resource base. Wood can be burned directly or gasified for power generation. This will reduce the need for future gas/coal imports.

10.4.9 Reducing Energy Demand

We need active steps to reduce overall demand for energy. A combination of energy pricing, regulations on energy efficiency, energy saving options can help to reduce demand for energy. For example, energy demand from transport is expected to grow very rapidly due to increase in personal vehicle numbers. Enormous fuel saving is possible if usage of public transport can be increased to reduce dependence on personal vehicles. On a per passenger basis, a bus uses several times less energy than a car. Also, if railways are able to win back the freight traffic from trucks and manage to carry 50 percent of freight billion tonne kilometre (Bt-km), then oil requirement can reduce substantially. These initiatives together, can reduce our transport oil requirement by over 25 percent from the most oil intensive scenario in 2031- 32. Similarly, demand for electricity can be reduced, if consumer demand for energy efficient equipment, lighting, and energy efficient buildings can be stimulated.

10.5 ADVERSE IMPACT OF CLIMATE CHANGE ON RENEWABLE ENERGY SOURCES

While we need to shift to renewable energy to mitigate climate impacts, climate change itself can adversely affect the renewable energy sources. Take for instance, hydropower. This is world's largest renewable energy source. But climate change may adversely affect the water bodies, the riverine system and the flow of water. This will constrain hydro power generation. Climate change will also affect the wind resource – its intensity and duration. This can affect the wind turbine capacity and extreme gales can damage the turbines, shortening the working life. Solar radiation can reduce by 20 per cent in some regions of the world due to cloud cover and can affect solar collection capacity. Even biomass can experience lower yield. Climate change can even reduce availability of cooling water in power plants when in competition with drinking water and irrigation. Climate mitigation is therefore critical for energy security and human survival.

Check Your Progress 2

Note: 1) Use the space given below for your answers.
2) Check your answers with those given at the end of this unit.

1. Briefly elaborate why energy intensity of our economic growth is coming down?

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2. List out the strategies needed for low carbon energy pathways.

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10.6 LET US SUM UP

Energy is the prime mover of economic growth and human survival. But more fuel we burn, more toxic and warming gases we emit. This harms public health as well as destabilizes climate. But energy demand and energy consumption will continue to grow to meet the economic and human development goals. There are solutions. Share the energy budget of the world equitably to allow all to meet the minimum threshold level of development. Specific strategies will be needed to shift to the low carbon energy systems. These include significant improvement in energy efficiency, adoption of low carbon energy pathways, renewable energy sources and curbing of energy demand. Proactive policies can accelerate energy transition.

10.7 KEYWORDS

Renewable Energy : Energy source like solar, wind, etc. that can be naturally replenished.

Non-renewable Energy: Fossil fuels that take extremely long time - millions of years to form.

Energy Intensity : Using energy more efficiently to produce a unit of output. The energy intensity will decline, if energy use is more efficient.

Energy Efficiency : Energy efficiency is the ratio between output of energy like light, heat, etc. and the input of energy. Lesser the energy input per output, more efficient is the process and less fuel we use.

Energy Security : To ensure adequate, affordable, reliable supplies of energy, diversity of primary energy mix and fuel substitution.

Demand Management : Policies that help to reduce consumer demand for targeted resource.

10.8 SUGGESTED FURTHER READING/ REFERENCES

World Energy Outlook, 2007, International Energy Agency

World Energy Outlook, 2008, International Energy Agency

Integrated Energy Policy 2006, Government of India

http://www.ipcc.ch/report/ar5/wg1/

http://www.ipcc.ch/report/ar5/wg2/

http://www.ipcc.ch/report/ar5/wg3/

http://www.ipcc.ch/report/ar5/syr/

https://www.globalchange.gov/climate-change/glossary

10.9 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. The different types of energy sources are
   a. Fossil energy – Petroleum, Coal, etc.
   b. Nuclear Energy
   c. Renewable energy – Geothermal, Wind, etc.
2. The traditional biomass is carbon neutral because the carbon that already exists in the atmosphere is absorbed during the growth of plants. During photosynthesis, the carbon is stored in the plant tissues and the oxygen is released. As the wood is burnt, the carbon present is released as CO_2 into the atmosphere.

Check Your Progress 2

1. The energy intensity of our economic growth is coming down and is about half of what it used to be in early seventies. This is done by adopting the efficiency measures.
2. The strategies needed for low carbon energy pathways are shifting to fuels with low carbon content and carbon intensity and also making use of renewable energy resources.